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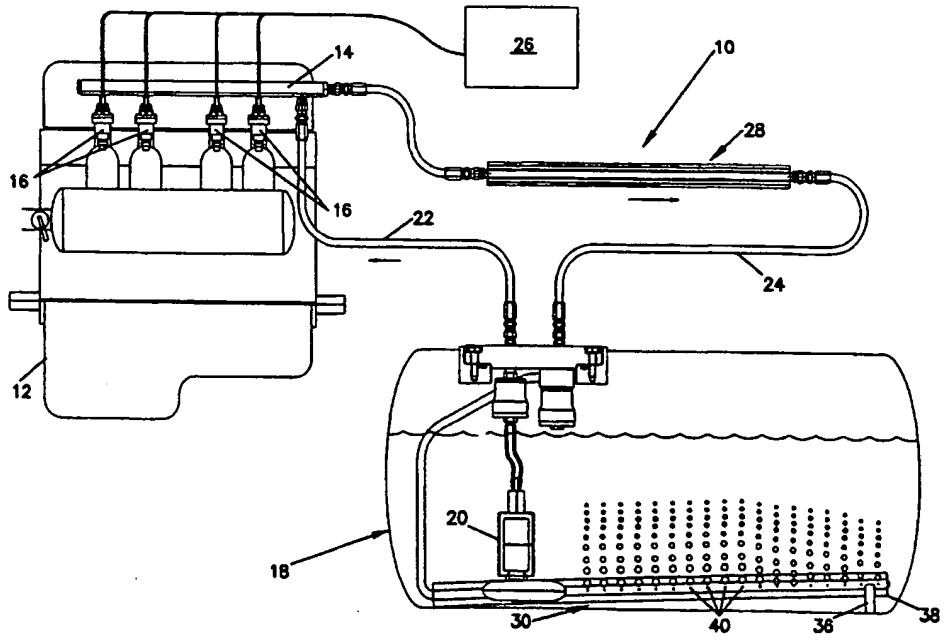

(57) Abstract

A fuel supply system and method for reducing the pressure in the fuel tank for a liquefied petroleum gas fuel supply system in which fuel is returned to the tank. Return fuel is cooled by heat transfer devices in the return line in line and in the tank.

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LIQUEFIED PETROLEUM GAS FUEL SYSTEM AND METHOD

Incorporation by Reference

Applicant's U.S. Patent Nos. 5,291,869; 5,325,838; and 5,423,303 are incorporated herein by reference.

Field of the Invention

This invention relates to a liquefied petroleum gas fuel injection system, and more particularly to a system and method for cooling return fuel in such systems.

Background of the Invention

Liquefied petroleum gas ("LPG") fuel supply systems are known, for example as shown in Applicant's U.S. Patent Nos. 5,291,869; 5,325,838; and 5,423,303. Such systems typically include a number of specialized fuel injectors which receive fuel from a high pressure tank. A fuel rail connected in-line with a series of injectors is often employed to deliver supply fuel to the injectors. In many systems, uninjected fuel is returned to the fuel tank. This is generally done to keep the supply fuel as cool as possible, particularly where it is intended to inject LPG in liquid rather than gaseous form.

One approach to injecting LPG without permitting it to vaporize is to pump high volumes of supply and return fuel. In this way, the supply fuel spends very little time near the heated engine compartment where it can vaporize. Another approach is to employ a refrigeration cycle as described in the Applicant's patents identified above. The evaporation of return fuel is used to cool supply fuel, thereby maintaining it in liquid form.

A problem with returning vaporized LPG to the fuel tank is that it can increase tank pressure substantially above the vapor pressure of the liquid in the tank. If the vapor does not condense before the pressure limit of the tank is exceeded, the pressure relief valve will release LPG vapor to the atmosphere. This is both unsafe and environmentally undesirable.

What has been needed is a way to cool return fuel in LPG systems so as to reduce the high fuel tank pressures which can occur.

Summary of the Invention

According to the present invention, an LPG fuel supply system and method are provided.

In one aspect of the system, the LPG system includes a plurality of fuel injectors operably connected to a fuel rail. The fuel rail is in fluid communication

with fuel supply and return lines. Both the fuel rail and injectors comprise an arrangement for cooling supply fuel with return fuel. A condenser in the return line cools return fuel.

In another aspect of the invention, the LPG fuel supply system comprises a plurality of fuel injectors in fluid communication with fuel supply and return lines. The fuel return line includes a mechanism for cooling return fuel.

In the method of the present invention, a liquefied petroleum gas fuel supply system is provided, comprising a plurality of fuel injectors in fluid communication with a fuel supply line and fuel return line. Vaporous fuel is produced in the fuel return line by the absorption of heat. The vaporous fuel is then cooled in the fuel return line prior to introducing it into the fuel in the fuel tank.

These and other advantages and features of novelty which characterize the invention are pointed out with particularity in the claims annexed hereto. However, for a better understanding of the invention and its advantages, reference should be made to the drawings which form a further part hereof, and to the accompanying descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

Brief Description of the Figures

Fig. 1 is a schematic diagram of a system according to the present invention; and

Fig. 2 is a cross-sectional view of condensers according to the present invention.

Detailed Description of Preferred Embodiment

Referring now to the drawings, wherein like numerals designate like parts throughout the figures, a fuel supply system 10 for providing LPG to an internal combustion engine 12 is shown. Applicant's U.S. Patent Nos. 5,291,869 ("'869 patent"), "LIQUEFIED PETROLEUM GAS FUEL SUPPLY SYSTEM," 5,325,838 ("'838 patent"), "LIQUEFIED PETROLEUM GAS FUEL INJECTOR," and 5,423,303 ("'303 patent"), "FUEL RAIL FOR INTERNAL COMBUSTION ENGINE" are also incorporated by reference and will be referred to herein as appropriate.

System 10 includes a fuel rail 14 which delivers fuel to a plurality of fuel injectors 16. Although a fuel rail is shown in the preferred embodiment, one is not necessary within the principles of the invention. For example, separate supply lines branching from a main supply line could deliver fuel to each injector in parallel.

In the preferred embodiment, both fuel rail 14 and injector 16 include arrangements for cooling supply fuel with return fuel, such as those described in the '869 patent generally, and more specifically in the '303 patent for the fuel rail and the '838 patent for the fuel injector. These arrangements involve evaporating return fuel in close proximity to supply fuel so as to extract heat from the supply fuel. In this way, supply LPG is maintained in liquid form when injected. It is not necessary, however, for the fuel rail or injectors to have such a refrigeration cycle, as there are other ways in which liquid LPG at injection can be achieved.

The main problem the present invention addresses is the high tank pressures which can result when heated LPG is returned to the fuel tank 18. Under the present regulations in the United States, the maximum allowable tank pressure is 312 psi. A pressure relief valve (not shown) would be opened if this maximum pressure is reached.

Return fuel is heated in its passage through the engine compartment by the engine itself. It can also be heated if a refrigeration cycle such as those in the preferred embodiment is employed. If the return line is routed under the chassis, engine, transmission, exhaust and radiator heat will also tend to be absorbed there. The problem is most pronounced at high engine and ambient temperatures and at low fuel levels.

Referring to Figs. 1 and 2, a system and method for addressing this problem will be described. In addition to the fuel injectors 16 and fuel rail 14 described above, system 10 includes fuel pump 20, supply line 22 and return line 24. As is generally the case, an engine control unit 26 controls injectors 16.

Return fuel is cooled in the preferred embodiment by in-line 28 and in-tank 30 condensers in return line 24. As shown in Fig. 2, condensers 28, 30 have external 32 and internal 34 fins to aid heat transfer. They are made of extruded aluminum.

In-line condenser 28, and as much of return line 24 as possible, are preferably located away from the hot underchassis. Cooler air can then assist in extracting heat from return fuel in condenser 28. If necessary, through ducting or otherwise, air can be forced across external fins 32 to further increase cooling. It may also be necessary to thermally insulate return line 24, as for example by surrounding with foam rubber.

In-line condenser 30 is immersed in fuel tank 18 at a terminal end of return line 24. Condenser 30 is placed below the fuel level in the tank so heat can be transferred to the liquid fuel. It is preferably mounted at the bottom of tank 18 to maximize exposure. Condenser 30 is elevated by legs 36 at its distal end 38 and has a plurality of vent holes 40 from which return fuel enters the fuel in tank 18. By this arrangement, gaseous fuel tends to be cooled along the entire length of condenser 30

before exiting near distal end 38. Spreading vent holes across tank 18 reduces the localized heat which would otherwise occur. Vent holes 40 are also preferably small, on the order of .03-.08 inches diameter, preferably .06 inches, to create smaller bubbles which will condense faster. The total flow area through vent holes 40 is preferably twice the cross-sectional area of return line 24 to minimize back pressure. While vent holes 40 are shown at approximately the horizontal quadrant of condenser 30, it may be preferable to position them lower to improve cooling.

The principle of cooling with a liquid could also be applied, for example, by cooling in-line with water or another liquid other than fuel.

Where both of the in-line 28 and in-tank 30 condenser are employed as described herein, cooling on the order of 200-500 watts or higher can be obtained. Whether one or both will be needed depends on the cooling needs of the particular system. The type and number of heat transfer devices and their size, shape and arrangement can also be varied within the principles of the invention.

WHAT IS CLAIMED IS:

1. A fuel supply system for providing liquefied petroleum gas to an internal combustion engine, comprising:

(a) a fuel rail in fluid communication with fuel supply and return lines, said fuel rail comprising a first arrangement for cooling supply fuel with return fuel;

(b) a plurality of fuel injectors operably connected to said fuel rail, said fuel injectors comprising a second arrangement for cooling supply fuel with return fuel; and

(c) a condenser in said return line.

2. A fuel supply system for providing liquefied petroleum gas to an internal combustion engine, comprising a plurality of fuel injectors in fluid communication with a fuel supply line, a fuel return line, and means in said return line for cooling return fuel.

3. A fuel supply system according to claim 2, wherein said cooling means comprise a condenser having external fins for transferring heat from the return fuel.

4. A fuel supply system according to claim 3, wherein said condenser also has internal fins for transferring heat.

5. A fuel supply system according to claim 2, wherein said cooling means are upstream of a fuel tank.

6. A fuel supply system according to claim 2, wherein said cooling means are in a fuel tank near a terminal end of said return line.

7. A fuel supply system according to claim 6, wherein said cooling means are mounted proximate a bottom of said fuel tank.

8. A fuel supply system according to claim 6, wherein said cooling means comprise a condenser having a fuel outlet proximate a distal end, constructed and arranged such that heat is absorbed by liquid fuel in the fuel tank from the return fuel as it flows toward said distal end.

9. A fuel supply system according to claim 8, wherein said condenser includes a plurality of vent holes spaced along its length, said holes being arranged such that gaseous fuel will tend to first exit said condenser proximate said distal end.

10. A method for reducing the pressure in a fuel tank for a liquefied petroleum gas fuel supply system for an internal combustion engine, comprising the steps of:

(a) providing a liquefied petroleum gas fuel supply system comprising a plurality of fuel injectors in fluid communication with a fuel supply line and a fuel return line;

(b) producing vaporous fuel in the fuel return line by the absorption of heat;

(c) cooling the vaporous fuel in the fuel return line prior to introducing it into the fuel in the fuel tank.

11. A method according to claim 10, wherein the step of cooling return fuel comprises cooling upstream of the fuel tank.

12. A method according to claim 11, wherein the step of cooling the vaporous fuel further comprises cooling by passing air over a heat transfer device.

13. A method according to claim 10, wherein the step of cooling the vaporous fuel comprises cooling with a liquid in conjunction with a heat transfer device.

14. A method according to claim 13, wherein the step of cooling the vaporous fuel further comprises immersing the heat transfer device in the fuel in the fuel tank.

15. A method according to claim 10, wherein the step of producing vaporous fuel includes cooling supply fuel prior to injection by evaporating return fuel in close proximity thereto.

FIG. 1

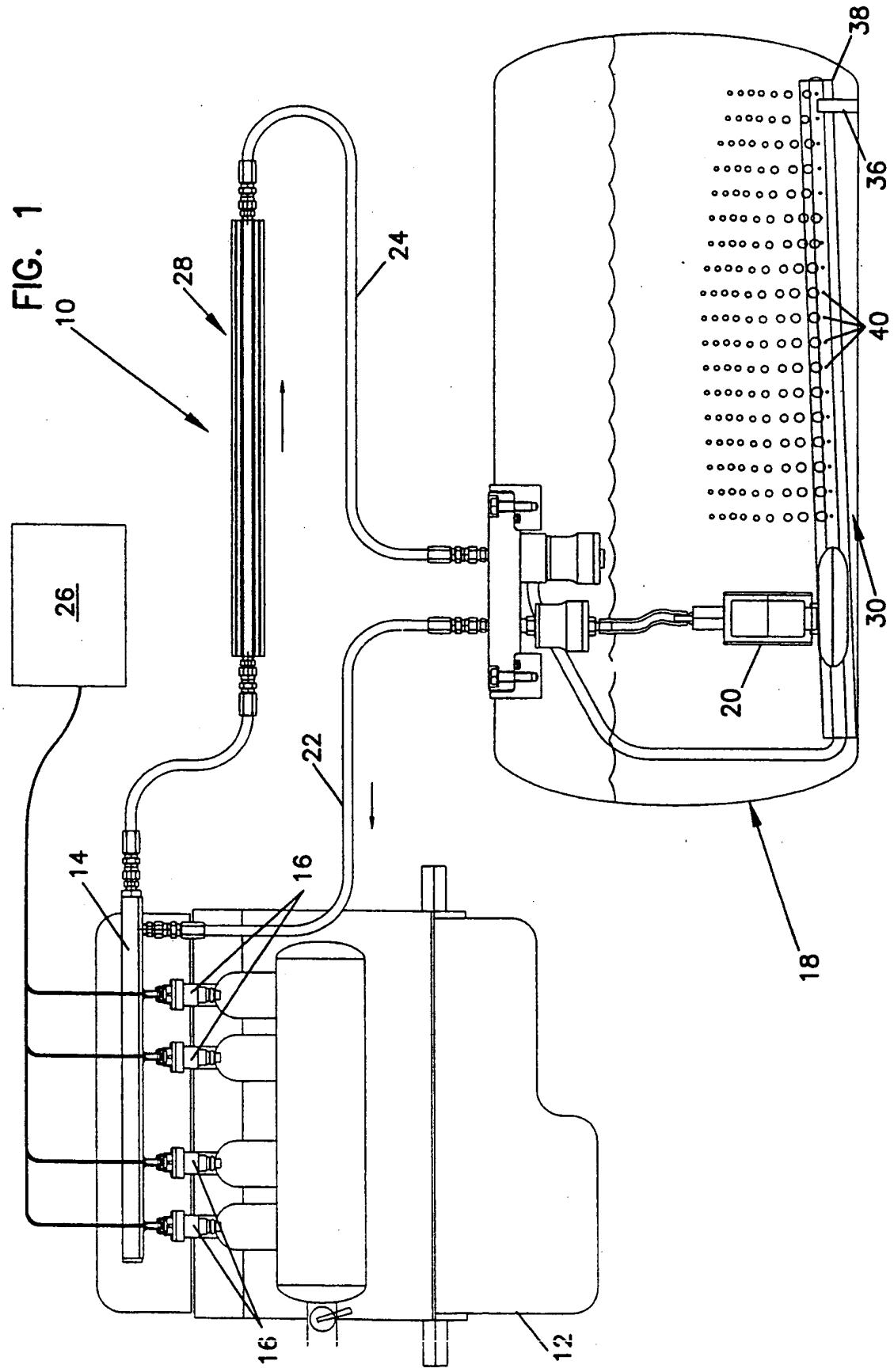
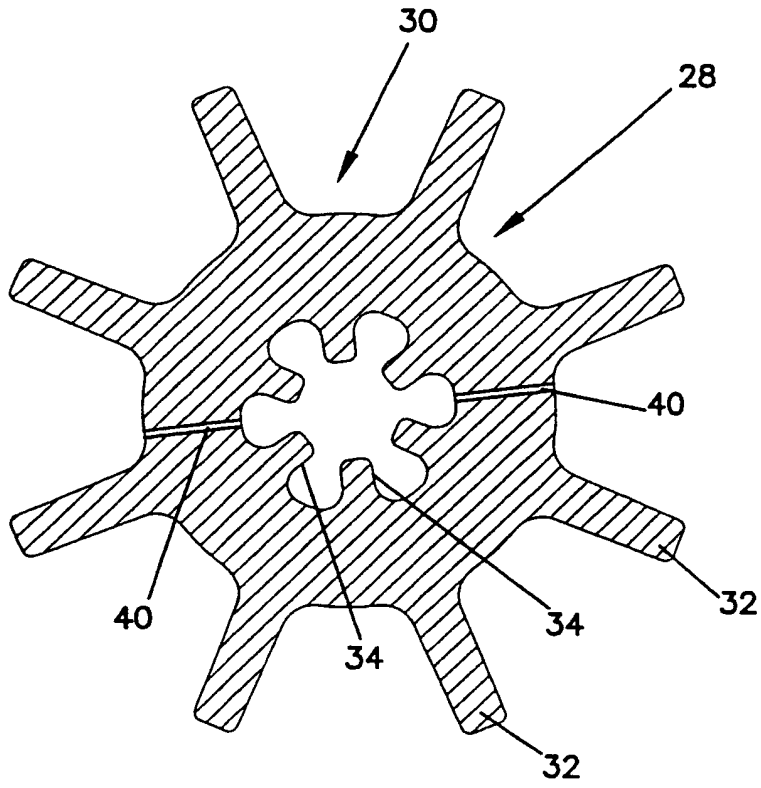


FIG. 2



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02M21/02 F02M31/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02M F02B F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 033 444 A (KAUFMAN ET AL.) 23 July 1991 see abstract see column 3, line 7 - line 58; figures 1-4	1,2,10, 13
A	US 5 291 869 A (BENNETT) 8 March 1994 cited in the application see abstract see column 3, line 9 - column 5, line 37; figures 1-4	1,2,10
A	US 4 938 036 A (HODGKINS ET AL.) 3 July 1990 see column 1, line 10 - line 25 see column 2, line 31 - column 4, line 55; figures 1-5	1-5,10, 11,13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 246 988 A (ROVER GROUP LIMITED) 19 February 1992 see abstract; figure 1 ---	14
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Information on patent family members

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